Space Weather Technical Forecast

Issued on Sunday, 16 July 2023 at 13:20 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Minor/Moderate R1/R2 Blackouts likely throughout G1-G2/Moderate likely Storms Day 2 (17 July), and possible Day 3 (18 Jul).

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Moderate, with only one short-duration M1 flare observed at 16/0826 UTC from AR3372 (in the northeast quadrant). There are currently up to eight sunspot regions on the visible disc. AR3363 persists as a large and mature spot. It seems to have stabilised but conserves some potential instability, due to a persistent delta spot. AR3372 is the other large region on the disc. It is slightly more complex but has lost a few spots in its intermediate section, having somewhat stabilised in the last 12 hours. However, it also contains a small delta spot and has produced some of the largest M-flares in recent history.

Several CMEs were observed leaving the sun over the past 24 hours, the largest and fastest originating from a region located well beyond the western horizon. A filament eruption was observed around 16/0830 UTC, originating from the northwest quadrant (just south of CH24). It may be Earth-directed but there is currently not enough satellite imagery to analyse it.

Figure 1. El Teide GONG imagery (left) showing the filament before it erupted, courtesy of the National Solar Observatory Integrated Synoptic Program (NSIP). Time-integrated AIA 211 dimming of the event (right), processing courtesy SIDC ROB.

The most recent CME originated from AR3363 around 16/0845 UTC but it is not considered to be Earth-directed.

Solar Wind / Geomagnetic Activity: The solar wind, as observed by ACE and DSCOVR at L1, was suggestive of a slow regime. The solar wind speed was steady and slowly declining from 410 to 350km/s with below average density. The total magnetic field (IMF), Bt, was largely weak and around 7nT throughout, with only small variations along the north-south component although mostly in opposition to the Earth's magnetic field. Phi angle was negative (Towards the sun). Geomagnetic activity was Quiet (Kp 0-2).

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Energetic Particles / Solar Radiation: High energy proton flux (greater than 10MeV), as observed by GOES16, became enhanced after 15/2050 UTC, most likely associated to a long duration flare that was observed shortly before. The flux rose above the S1 threshold between 16/0630-0910 UTC, reaching a peak of 18pfu at 16/0735 UTC, before slowly coming back down during the following hours. High energy electron flux (greater than 2MeV) was at background levels. The 24-hour integrated fluence was below the Active (1e8 integrated pfu) threshold on a decreasing trend. A fluence of 1.17e6 pfu was recorded at 16/0000 UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: Activity is expected to remain Moderate, with occasional M-class flares and a slight chance of X-class flares. The most likely source of flares is currently AR3372 but AR3363 (in the southwest quadrant) remains a good candidate.

Solar Wind / Geomagnetic Activity: Earth is likely to see a CME arrive on day 2 (17 Jul) from the combined C8.8 flare and filament eruption on the 14 Jul. The strength of any impact is low confidence, due to uncertainties about the material content of any CME, along with limited imagery for analysis, however this is currently expected to arrive 17/1400 +/- 10 hours. Otherwise solar winds are likely to ease towards background day 1 (16 Jul), and again once any CME influence subsides later day 3 (18 Jul). There is a slight chance of a small enhancement from the HSS of CH25 later day 4 (19 Jul). Mainly Quiet geomagnetic activity is expected to become Active to G2 Moderate storm during the second half of day 2 (17 Jul). These conditions gradually easing day 3 (18 Jul) to be mainly Quiet by day 4 (18 Jul). There is a slight chance of activity rising again to Unsettled to Active with any CH HSS enhancement from CH24.

Energetic Particles / Solar Radiation: The high energy (greater than 10MeV) proton flux has a slight chance of reaching the S1/Minor Storm threshold through the period, should any large flares occur. However the probability is low and expected to decrease over the following days. An increase in observed flux may also occur just ahead of the CME arrival expected on day 2 (17 Jul) High energy electron flux (greater than 2MeV) is expected to be at mostly background, perhaps briefly Moderate however fluence is most likely to remain below the Active (1e8 integrated pfu) threshold throughout.

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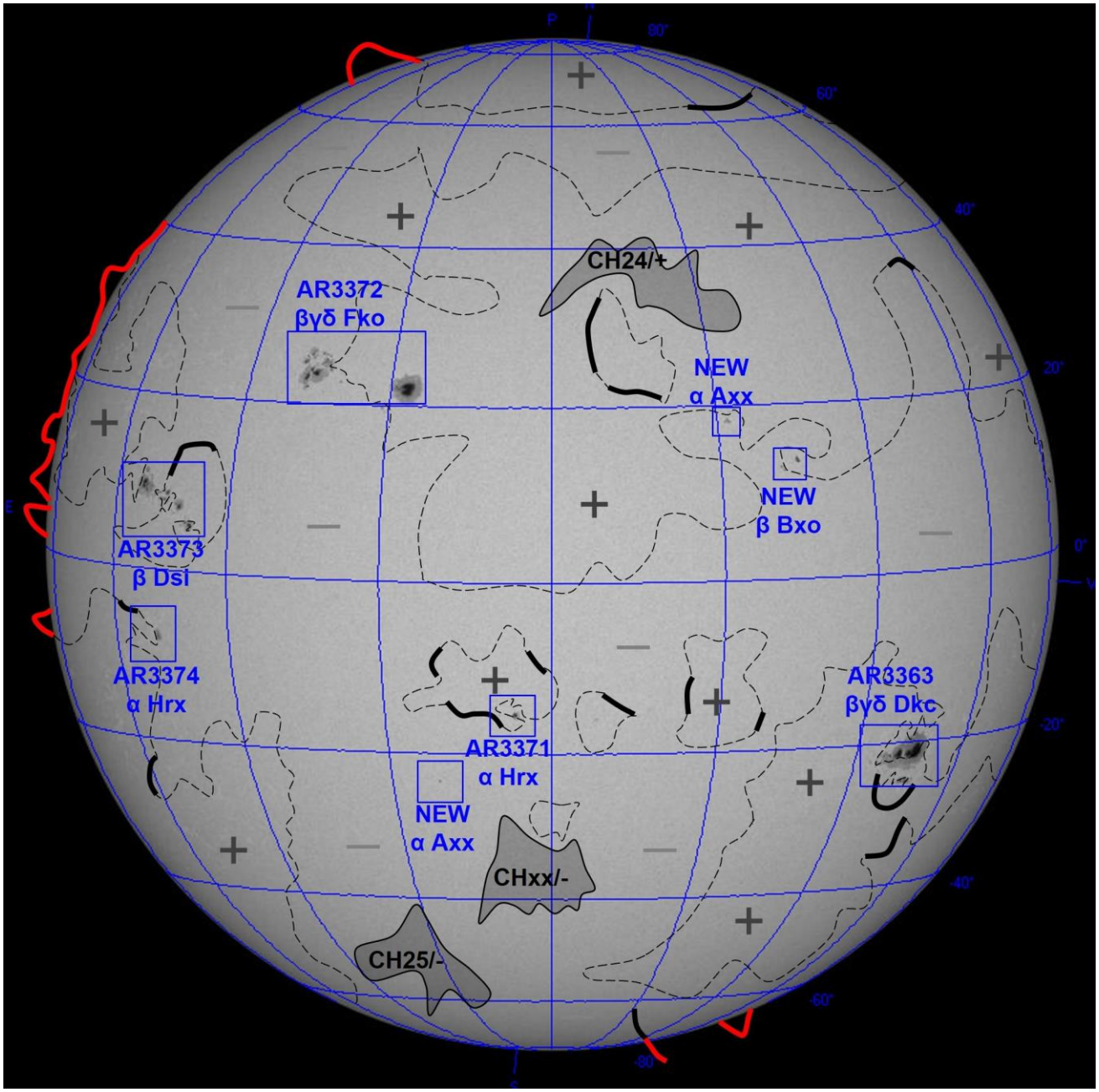
Figure 2. Solar Analysis Valid 16/0800 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

There is one Earth-directed CME in the forecast, however confidence is low regarding the bulk material content of the CME. This left the Sun on 14 Jul from a combination C8.8 flare of AR3370 and associated filament lift, the latter of which is clearly visible as dark plasma moving westwards across SDO aia-304. A complex and faint CME signature in SOHO imagery followed however available imagery is currently very limited, with other not Earth-directed CME events also obscuring the visibility. Overall, a CME arrival is anticipated to arrive on day 2 at around 17/1400 +/- 10 hours, however the strength of any arrival is very low confidence. This is slightly delayed compared to MOSWOC enlil due to the uncertainty in the analysis.

Not much coronal hole influence otherwise, at least initially, with solar winds expected to remain largely at background levels on day 1 (16th). They might become slightly elevated on days 2 and 3 (17th &18th) in response to the CME from the 14th, as suggested by Enlil and Ensembles members, before slowly coming back to background levels by day 4 (19th). There is a chance of a slight increase in solar winds later on day 4 (19 Jul) from CH24 HSS, however only a limited enhancement is currently expected

Mainly Quiet geomagnetic activity is expected to become Active to G2 Moderate storm during the second half of day 2 (17 Jul), with a slight chance of G3 Strong Storms. These conditions gradually easing day 3 (18 Jul) to be mainly Quiet by day 4 (18 Jul). There is a slight chance of activity rising again to Unsettled to Active with any CH HSS enhancement from CH24.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	1	60	40	5
Strong	G3	No	1	20	10	1
Severe	G4	No	1	2	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
14/2155	Asymmetric full	C8.8 flare of AR3370 and filament eruption	S centre disc	832 km/s	17/1400 UTC	Low confidence on strength of impact. Limited imagery for analysis.

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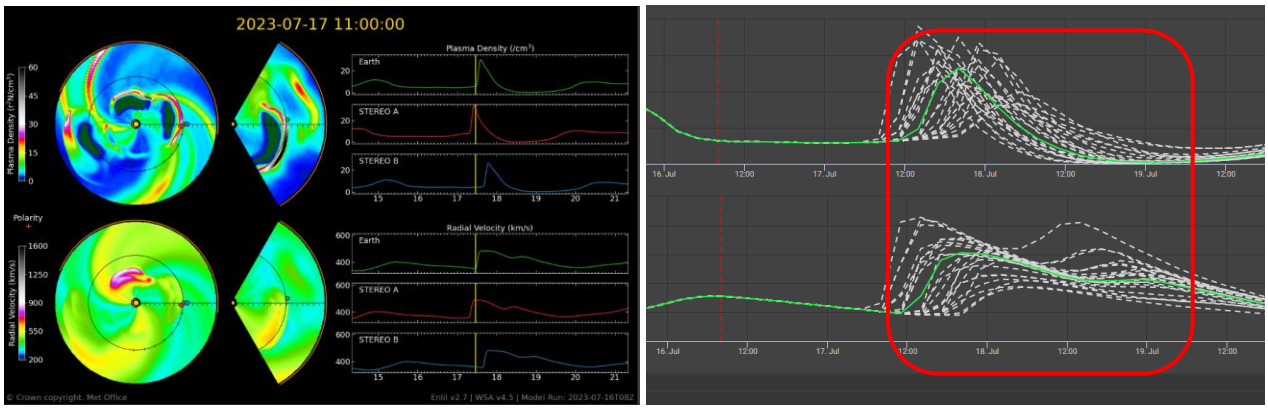
Figure 3: MOSWOC Enlil and ensemble, showing a possible CME arrival on the 17th , with impacts continuing into the 18th



Radio Blackouts - X-Ray Flares:

Solar activity has been Moderate, with only one short-duration M1 flare observed at 16/0826 UTC from AR3372 (in the northeast quadrant).

There are currently up to eight sunspot regions on the visible disc. AR3363 persists as a large and mature spot. It seems to have stabilised but conserves some potential instability, due to a persistent delta spot. AR3372 is the other large region on the disc. It is slightly more complex but has lost a few spots in its intermediate section, having somewhat come to maturity. However, it also contains a small delta spot and has produced some of the largest M-flares in recent history. AR3373 is moderately sized but currently appears to have a relatively simple magnetic structure. AR3367 may still be active but is now too close to the western horizon to be seen and has therefore been removed from the tables. The other regions are all smaller, and simpler.
Activity is expected to remain Moderate, with occasional M-class flares and a slight chance of X-class flares. The most likely source of flares is currently AR3372 but AR3363 (in the southwest quadrant) remains a good candidate.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	60	60	60	60
Very Active	R3 to R5 X Class	No	10	10	10	10

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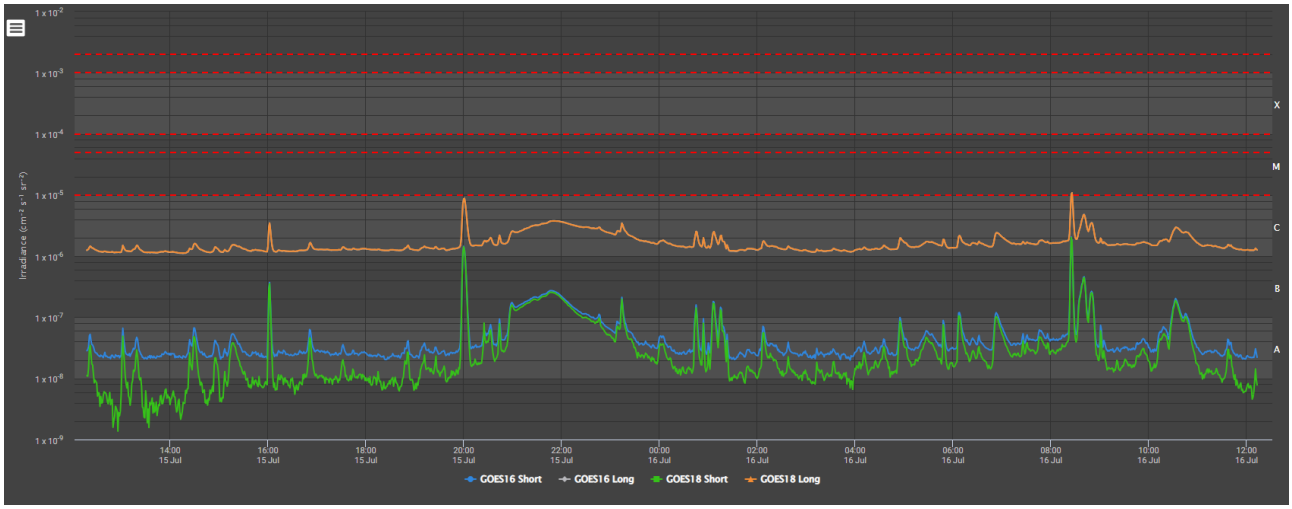
Figure 4: Latest X-ray flare activity, as observed by GOES-16.



Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux, as observed by GOES16, has unexpectedly risen above the S1 threshold, reaching a peak of 18pfu at 16/0735 UTC. This rise was most likely in response to a long duration flare that was observed around 15/2150 UTC. This was followed by several CMEs from over the western limb, implying a much stronger flare on the far side. The current enhancement is expected to slowly decline over the following hours and come back below the S1 threshold.

Further slight increases in proton flux are possible, however the probability of reaching the S1 threshold is rather low and expected to decrease over the following days, as the associated sunspot region rotates further away from the western horizon. The arrival of a CME on day 2 (17 Jul) may collect up protons ahead of it, resulting in a brief increase before flux then decreases again once it passes. This brings a slight chance of reaching the S1 threshold.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	Yes	30	20	10	10
Very Active	**≥ S3 ***	No	5	1	1	1

* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)

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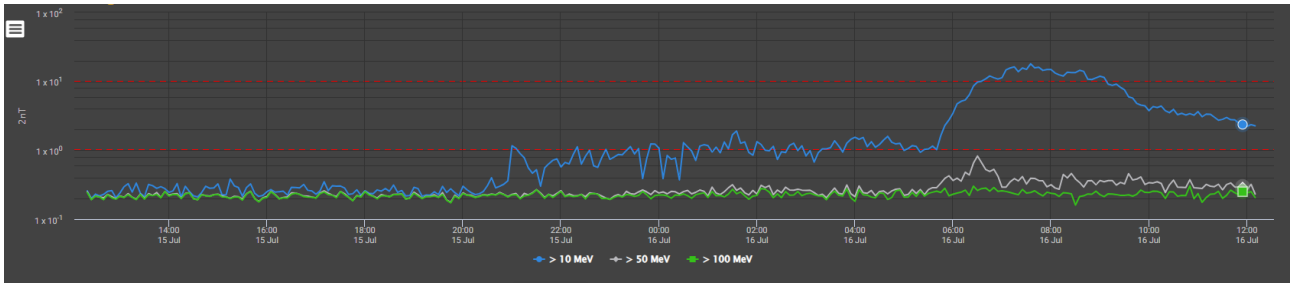
Figure 5: Latest Proton Flux, as observed by GOES-16, showing the S1 threshold being reached.



High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) at GEO has been at mostly background levels. Background flux, perhaps rising to Moderate briefly on day 1 and perhaps early day 2 (16 and 17 Jul), is expected to persist until at least later on day 3 or day 4 (18 or 19 Jul), as any CME influences arriving on day 2 decline.

The associated 24-hour fluence is expected to remain below the Active (1e8 integrated pfu) threshold, with REFM giving a reasonable guide, although it won't be taking account of any CME arrivals. It is expected that fluence will remain below Active levels throughout.

GEO Electron Environment	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	No	1	1	5	10
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	1	1

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